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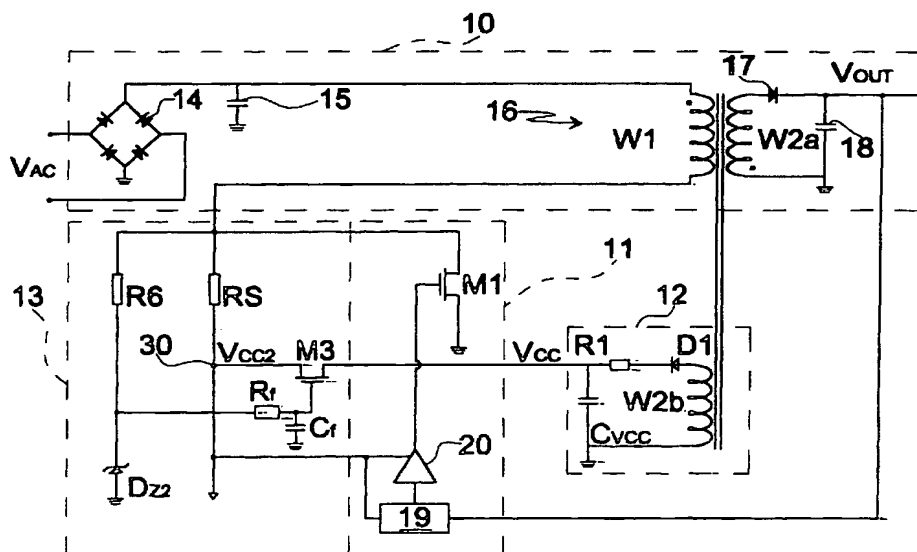
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(54) Title: BOOTSTRAP CIRCUIT FOR SWITCHING POWER SUPPLIES



(57) Abstract: The present invention refers to a starting circuit for switching power supplies (SMPS), to a switching power supply comprising a starting circuit and an integrated circuit of a switching power supply. In an embodiment thereof the starting circuit (13) for switching power supplies having a first supply voltage (V_{in}) coming from a first terminal and a second supply voltage (V_{cc}) coming from a second terminal and a third terminal (30); said starting circuit comprises: a first current path between said first terminal and said third terminal (30); a second current path between said first terminal and said second terminal; a third current path between said second terminal and said third terminal (30); a two-way voltage regulator (M3, Dz2, R5, R6) placed along said second current path.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

"Starting circuit for switching power supplies."

* * * *

DESCRIPTION

5 The present invention refers to a starting circuit for switching power supplies (SMPS), to a switching power supply comprising a starting circuit and to a switching power supply integrated circuit.

Most of the control integrated circuits for switching power supplies require for their starting a current to charge a capacity of the self supply circuit of the integrated circuit. Such current comes from the starting circuit
10 (start-up), constituted in the simplest case by a resistance connected to the supply line.

When the voltage on the capacity achieves a preset voltage value called start-up voltage, the control circuit is supplied by the self supply circuit. The self supply circuit is generally constituted by an additional winding
15 performed on the main transformer of the switching power supply to which a suitable rectification and filtration circuit is connected.

Since lately there are more and more severe requests for the reduction of the supply consumption, the simple above mentioned resistance is replaced by circuits active during the starting phase and inactive during the normal
20 operation.

Lately there are also demands to have some monolithic devices for the switching power supplies that comprise both the control circuit and the starting circuit (active).

However, the technologies used for these integrated circuits, for
25 instance that denominated RESURF (REduced SURface Field), have limitations as regards the maximum sustainable voltage between source/body of the transistor DMOS and the substrate. The control of the charge present in the epitassial layer, necessary for the component sustainable voltage, does not allow to guarantee punch-through voltages
30 higher than about 20V.

The realization of thick epitaxial layers allows to increase the punch-through voltage, but it has as result the complication of the industrial process and a cost increase.

5 In view of the state of the art described, it is an object of the present invention to provide a device, preferably monolithic, that eliminates the pressing voltage limitations of maximum supply voltage applicable to the device itself, that is realized with standard technologies, or without having to use new technologies and therefore through a low cost solution.

10 According to the present invention, such an object is achieved by a starting circuit for switching power supply having a first supply voltage coming from a first terminal and a second supply voltage coming from a second terminal and a third terminal; said starting circuit comprising: a first current path between said first terminal and said third terminal; a second current path between said first terminal and said second terminal; a third
15 current path between said second terminal and said third terminal; characterized by further comprising a two-way voltage regulator placed along said second current path.

20 According to the present invention, such an object is also achieved by a switching power supply comprising a control circuit of said switching power supply; and a starting circuit of said control circuit according to the claim 1.

25 According to the present invention, such an object is further achieved by an integrated circuit of a switching power supply comprising a control circuit of said switching power supply; and a starting circuit according to the claim 1 able to sustain a self supply voltage greater than 40 V, more preferably greater than 80 V, and even more preferably greater than 160 V.

30 Thanks to the present invention it is possible to realize a two-way starting circuit that alternatively constitutes a path of low impedance that allows the passage of current from the main power supply toward the integrated circuit or to stabilize and to limit the maximum voltage applied to the inside circuits of the integrated circuit when it is fed by the auto supply

circuit.

The features and the advantages of the present invention will be made more evident by the following detailed description of a particular embodiment, illustrated as a non-limiting example in the annexed drawings, wherein:

Figure 1 shows a block scheme of a switching power supply comprising a starting circuit according to a first embodiment of the known art;

Figure 2 shows a block scheme of a switching power supply comprising a starting circuit according to a second embodiment of the known art;

Figure 3 shows a block scheme of a switching power supply comprising a starting circuit according to a first embodiment of the present invention;

Figure 4 shows a block scheme of a switching power supply comprising a starting circuit according to a second embodiment of the present invention.

Referring now to Figure 1, that shows a block scheme of a switching power supply comprising a starting circuit 13 according to a first embodiment of the known art, a circuit 10 of rectification and filtration of the main supply, a self supply circuit 12 and a control circuit 11 of the circuit 10 of rectification and filtration of the main supply.

The circuit 10 of rectification and filtration of the main supply receives in input the supply voltage V_{ac} of the power network, rectifies it through a diode bridge 14, filters it through a capacitor 15, and it provides it to the warm terminal of the primary winding $W1$ of a transformer 16. The secondary winding $W2a$ of the transformer 16 provides the voltage present at its terminals to a rectifier diode 17 and to a filter capacitor 18. The circuit 10 provides the output voltage V_{out} to its output.

The control circuit 11, of the circuit 10 of rectification and filtration of the main supply, receives in input the output voltage V_{out} , this voltage is elaborated, in a known way, by an elaboration circuit 19, and provided to a driving circuit 20 of a power transistor $M1$ connected to the cold terminal of the secondary winding $W1$ of the transformer 16.

The self supply circuit 12 includes another secondary winding W2b, which provides the voltage at its terminals to a diode D1 in series with a resistance R1 and then to a capacitor Cvcc, to whose terminals the supply voltage Vcc will be available. The voltage Vcc is used for the supply of the control circuit 11 and of all the other circuits, not shown, necessary for the operation and the control of the switching power supply.

The starting circuit 13, in this case, is constituted by a simple resistance Rs connected between the cold terminal of the primary winding W1 and Vcc. The voltage present on the cold terminal of the primary winding W1 is denominated Vin.

At the starting of the switching power supply, the capacitor Cvcc is charged by the starting circuit 13 as the voltage is not yet present on the secondaries of the transformer 16. At the increasing of the voltage on the terminals of the capacitor Cvcc, all the circuits of the switching power supply are activated and the circuits are supplied by the voltage Vcc provided by the self supply circuit 12.

The use of a simple resistance as starting circuit 13 simplifies notably the circuit but being always active it consumes a great amount of current. Therefore solutions having a reduced consumption have been found as for instance that shown in Figure 2, where the components similar to those of Figure 1 have the same numerical references.

In Figure 2 the starting circuit 13 is more complex and active. It includes a transistor M2 having the drain connected to the voltage Vcc and the source to a current generator 21 that provides the current to the capacitor Cvcc. On the gate of the transistor M2, a reference voltage produced by a resistance R2 placed in series with a zener diode DZ1 is applied, they are connected between the voltage Vin and ground. In parallel to the zener diode DZ1 there is a controlled switch S. A voltage divider composed by the resistances R3 and R4 is connected between the voltage Vcc and ground. The voltage picked in the connection node between the resistance R3 and the

resistance R_4 is applied to an input of the comparator UVLO, at the other comparator input a reference voltage V_{ref} is applied. The output of the comparator UVLO controls the controlled switch S .

5 In this case, at the starting of the switching power supply, the capacitor C_{vcc} is charged through the starting circuit 13, the transistor M_2 being active (because supplied by the voltage V_{in}). When the voltage V_{cc} overcomes a preset value, or when the voltage provided by the voltage divider R_3 and R_4 overcomes the voltage reference V_{ref} , the controlled switch S is closed and stops the passage of current between V_{in} and the
10 circuits of the switching power supply. At this point the voltage V_{cc} is enough to supply the circuits of the switching power supply, and it is eliminated or at least it reduces the current consumption due to the starting circuit 13.

To be noted at this point that the voltage at the terminals of the
15 secondary winding W_{2b} is a squared wave V_{sq} that, filtered by the circuit D_1 , R_1 , C_{vcc} , is changed into a continuous voltage V_{cc} that is the voltage supply of the integrated. The parasitic inductance associated to the primary winding provokes some impulses during the switching transient for which the voltage V_{SQ} is not a perfect squared wave but it has some impulses
20 whose amplitude increases at the increasing of the load in output.

The voltage V_{cc} , obtained by filtering the voltage V_{sq} , could exceed the maximum value applicable and the system would be switched off by the circuit OVP (Over Voltage Protection), not shown.

25 The self supply circuit 12 is in fact a peak detector and it detects the voltage impulses of V_{sq} .

The resistance R_1 is used to clip the impulses V_{sq} in order to minimize the effects and it resolves the problem when the load is high, but, when the load is low, it becomes a drawback because, in this case, the voltage V_{sq} shows some rounded edges and V_{cc} can result of a lower value than the
30 minimum applicable with consequent turning off of the system.

To that a light dependence with the input voltage is to be added, that can vary of a factor greater than to 3:1 in systems with universal supply.

5 The voltage value V_{cc} can be very different according to the operational conditions but however it has to be comprised between the minimum turning off voltage and the maximum voltage admissible.

Therefore it is necessary to experimentally find the excellent value of R_1 , that allows to satisfy both the aforesaid conditions, and this sometimes results not to be possible so that it is necessary to modify the secondary winding W_{2b} .

10 We now refer to Figure 3 that shows a block scheme of a switching power supply comprising a starting circuit according to a first embodiment of the present invention.

This Figure is similar to Figure 1, where the components similar to those of Figure 1 have the same numerical references.

15 In this Figure a transistor M_3 has been inserted between the terminal of V_{cc} and the terminal 30 that is the terminal to which the resistance R_s is connected and is also that on which the voltage V_{cc2} , that supplies all the circuits of the switching power supply, is available. Particularly the transistor M_3 has the drain connected to the terminal V_{cc} and the source to
20 the terminal 30. A reference voltage is produced by a resistance R_6 placed in series to a zener diode DZ_2 , connected between the voltage V_{in} and ground. This reference voltage goes through preferably a low pass filter constituted by a resistance R_f and by a capacitor C_f and then is applied to the gate of the transistor M_3 .

25 At the starting of the switching power supply the capacitor C_{vcc} is charged by the resistance R_s , as the transistor M_3 is in conduction and its symmetrical structure allows that it operates in the third quadrant, that is the drain behaves as a source and vice versa.

30 When the voltage V_{cc} increases, the transistor M_3 works in the first quadrant, with the drain connected to the terminal V_{CC} and the source

connected to the terminal 30, and it supplies all the circuits of the integrated circuit. The gate of the transistor M3 is connected to the cathode of the diode DZ2 so that the supply voltage of Vcc2 of the internal circuits of the integrated circuit will be equal to the breakdown voltage of the zener diode DZ2 less the gate-source voltage of the transistor M3 and it will be independent from the voltage VCC, voltage that can increase up to the breakdown value of the transistor M3. Any limit on Vcc is so eliminated consequent to the voltage limitation of the transistors source.

The filter composed by the resistance Rf and by the capacitor Cf are used to sustain the transistor M3 gate voltage when at every switching cycle the voltage Vin is brought to ground by the transistor M1.

The transistor M3 can sustain high voltages between the drain and the source while the electric circuits of the integrated circuit sustain medium - low voltages limited by the zener diode Dz2 and by the transistor M3.

We refer now to Figure 4 that shows a block scheme of a switching power supply comprising a starting circuit according to a second embodiment of the present invention.

This Figure is similar to Figure 2, where components similar, to those of Figure 2 have the same numerical references.

Also in this case a transistor M3 has been inserted between the terminal of Vcc and the terminal 30 that is the terminal to which the current generator 21 is connected and is also that on which there is available the voltage Vcc2 that supplies all the circuits of the switching power supply. Particularly the transistor M3 has the drain connected to the terminal Vcc and the source to the terminal 30. A reference voltage is produced by a resistance R5 placed in series with a zener diode DZ2 and then with a zener diode DZ1, connected between the voltage Vin and ground. The reference voltage, available on the terminals of the diode DZ2, preferably goes trough a low pass filter constituted by a resistance Rf and by a capacitor Cf and then it is applied to the transistor gate M3.

The connection node between the diodes DZ2 and DZ1 is connected to the transistor M2 gate. In parallel to the diode DZ1 the controlled switch S, controlled by the comparator UVLO, is placed.

5 At the increasing of the voltage V_{cc} , the controlled switch S is closed and it short-circuits the diode DZ1, interrupting the current flow through the transistor M2, and the voltage regulator composed by the transistor M3, by the diode DZ2 and preferably by the filter composed by R_f and C_f starts to work.

10 Preferably, the control circuit 11, the starting circuit 13 and eventually other necessary circuits for the operation and the control of the switching power supply (not shown) are contained in one integrated circuit. It is so obtained an integrated circuit, using a standard type technology (for instance able to sustain a voltage between the source/body and the substrate of around 20 Vs) able to sustain a very high voltage V_{cc} (between drain and
15 ground), greater than 40 V, more preferably greater than 80 V, and even more preferably greater than 160 V (for instance equal to the breakdown voltage of about 700 Vs).

CLAIMS

1. Starting circuit (13) for switching power supplies having a first supply voltage (Vin) coming from a first terminal and a second supply voltage (Vcc) coming from a second terminal and a third terminal (30); said starting circuit comprising: a first current path between said first terminal and said third terminal (30); a second current path between said first terminal and said second terminal; a third current path between said second terminal and said third terminal (30), characterized by further comprising a two-way voltage regulator (M3, Dz2, R5, R6) placed along said second current path.
2. Starting circuit for switching power supplies according to claim 1, characterized in that said two-way voltage regulator (M3, Dz2, R5, R6) comprises a voltage limiting circuit (R5, R6, Dz2) supplied by said first supply voltage (Vin).
3. Starting circuit for switching power supplies according to claim 1, characterized in that said two-way voltage regulator (M3, Dz2, R5, R6) comprises a transistor (M3) having the drain coupled to said second terminal and the source coupled to said first and to said third terminal (30).
4. Starting circuit for switching power supplies according to claim 3, characterized in that said two-way voltage regulator (M3, Dz2, R5, R6) comprises a preset voltage generator (R5, R6, Dz2) coupled to said transistor (M3) gate.
5. Starting circuit for switching power supplies according to claim 3, characterized in that said two-way voltage regulator (M3, Dz2, R5, R6) comprises a capacitor (Cf) coupled to said transistor (M3) gate.
6. Starting circuit for switching power supplies according to claim 1, characterized in that said first current path comprises a resistance (Rs).
7. Starting circuit for switching power supplies according to claim 1, characterized in that said first current path comprises a controlled switch (S).
8. Starting circuit for switching power supplies according to claim 1,

characterized in that said controlled switch (S) is closed when said second supply voltage (Vcc) is lower than a preset reference voltage value and it is open when said second supply voltage (VCC) is higher than said preset reference value.

5 9. Switching power supply comprising a control circuit (11) of said switching power supply; and a starting circuit (13) of said control circuit according to claim 1.

10 10. Integrated circuit of a switching power supply comprising a control circuit of said switching power supply; and a starting circuit (13) according to claim 1 able to sustain a self supply voltage (Vcc) greater than 40 V, more preferably greater than 80 V, and preferably even greater than 160 V.

"Starting circuit for switching power supplies."

* * * *

ABSTRACT

5 The present invention refers to a starting circuit for switching power
supplies (SMPS), to a switching power supply comprising a starting circuit
and an integrated circuit of a switching power supply. In an embodiment
thereof the starting circuit (13) for switching power supplies having a first
supply voltage (V_{in}) coming from a first terminal and a second supply
voltage (V_{cc}) coming from a second terminal and a third terminal (30); said
10 starting circuit comprises: a first current path between said first terminal and
said third terminal (30); a second current path between said first terminal
and said second terminal; a third current path between said second terminal
and said third terminal (30); characterized by further comprising a two-way
voltage regulator (M3, Dz2, R5, R6) placed along said second current path.
15 (Fig. 3).

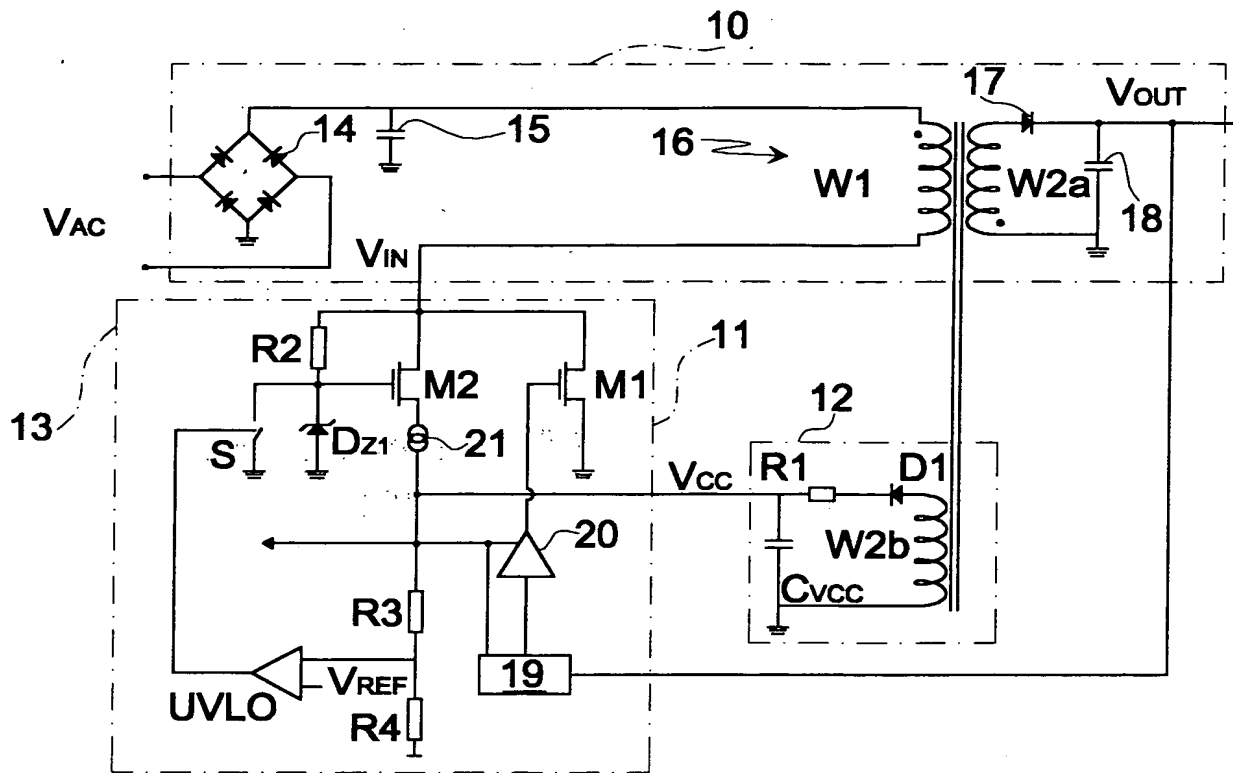


Fig.2

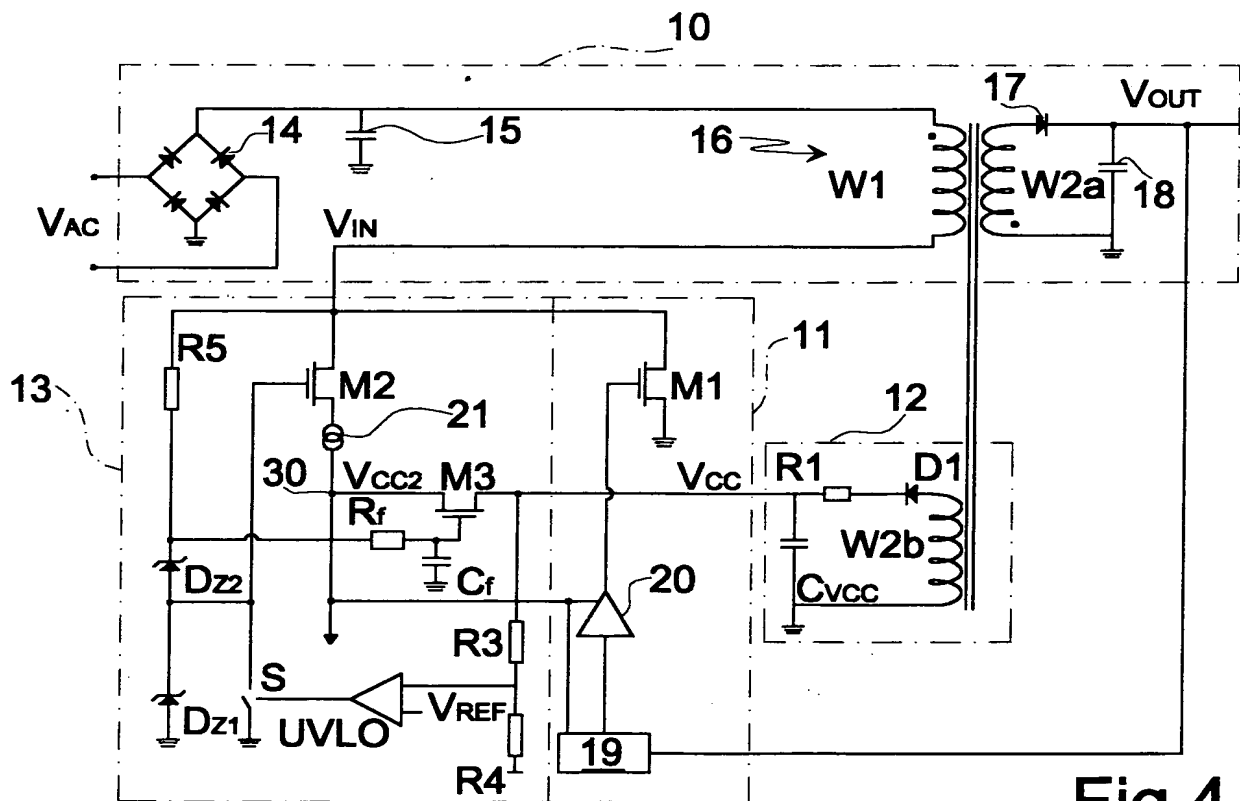


Fig.4

INTERNATIONAL SEARCH REPORT

Internat Application No
PCT/IT 02/00478

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H02M1/00 H02M3/335

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H02M H03K G05F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, IBM-TDB, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 880 942 A (LEU FANG-JYE) 9 March 1999 (1999-03-09) column 4, line 21 -column 5, line 3; figures 2,3	1,6-9
X	PATENT ABSTRACTS OF JAPAN vol. 2000, no. 21, 3 August 2001 (2001-08-03) & JP 2001 103743 A (NAGANO JAPAN RADIO CO), 13 April 2001 (2001-04-13) abstract	1,6-9
X	EP 0 585 788 A (POWER INTEGRATIONS INC) 9 March 1994 (1994-03-09) abstract; figures 1-4	1,3,7-10
	-/--	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

- *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- *&* document member of the same patent family

Date of the actual completion of the international search

12 February 2003

Date of mailing of the international search report

27/02/2003

Name and mailing address of the ISA

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INTERNATIONAL SEARCH REPORT

Internat	Application No
PCT/IT	02/00478

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 1999, no. 07, 31 March 1999 (1999-03-31) & JP 02 294277 A (BABCOCK & WILCOX CO:THE), 5 December 1990 (1990-12-05) abstract	1,2,6-9
A	--- BASSO C: "TRANSISTOR PAIR LOWERS PWM IC'S START-UP CURRENT" EDN ELECTRICAL DESIGN NEWS, CAHNERS PUBLISHING CO. NEWTON, MASSACHUSETTS, US, vol. 44, no. 6, 18 March 1999 (1999-03-18), page 128 XP000887678 ISSN: 0012-7515 the whole document	1-10
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/IT 02/00478

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☒ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
see FURTHER INFORMATION sheet PCT/ISA/210
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box I.2

Present claims 1, 2, 6 to 10 relate to devices defined by reference to a desirable characteristic or property, namely a voltage regulator operating in a two-way (bidirectional) mode.

The claims cover all apparatus having this characteristic or property, whereas the application provides support within the meaning of Article 6 PCT and disclosure within the meaning of Article 5 PCT for only a very limited number of apparatus. In the present case, the claims so lack support, and the application so lacks disclosure, that a meaningful search over the whole of the claimed scope is impossible. Independent of the above reasoning, the claims also lack clarity (Article 6 PCT). An attempt is made to define the device by reference to a result to be achieved (in claim 10 a reference is also made to the capability of sustaining a self supply voltage). Again, this lack of clarity in the present case is such as to render a meaningful search over the whole of the claimed scope impossible. Consequently, the search has been carried out for those parts of the claims which appear to be clear, supported and disclosed, namely those parts relating to the devices corresponding to the schematics of figures 3 and 4.

The applicant's attention is drawn to the fact that claims, or parts of claims, relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure.

INTERNATIONAL SEARCH REPORT

Information on patent family members

Internat Application No

PCT/IT 02/00478

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